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AIR FORCE FLIGHT DYNAMICS LABORATORY

DIRECTOR OF LABORATORIES

AIR FORCE SYSTEMS COMMAND

WRIGHT PATTERSON AIR FORCE BASE OHIO



FBC 4162

USER'S INSTRUCTIONS FOR THE COMPUTER PROGRAM PLSTR AS MODIFIED BY AFFDL/FBC

Prepared by

PLSTR

T. Muha

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February 1973

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FOREWORD

This work was conducted by Mr T. J. Muha, Exploratory Development Group, Advanced Composites Branch, at the Air Force Flight Dynamics Laboratory, under Project 4364, "Filamentary Composites Structures."

The manuscript was released by the author in February, 1973. This Technical Memorandum has been reviewed and is approved.

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Chief, Advanced Composites Branch

Structures Division

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PART I

GENERAL INFORMATION

1.1 BACKGROUND

PLSTR was written by Dr R. S. Sandhu of the Ohio State University.

The coding was based upon the earlier work by Professor Wilson of the

University of California at Berkley, but modifications were made to

improve the program's efficiency. The present version in use by AFFDL/

FBC includes modifications by Mr T. J. Muha to account for orthotropic

materials and to permit the output of either maximum and minimum stresses

or strains.

1.2 PROGRAM DESCRIPTION

This program performs an elastic, plane stress, finite element, structural analysis. It can handle linearly varying thermal and pressure loads. At the present time it can handle quadrilateral and triangular elements, up to three thousand elements or grid points, up to twelve materials, up to eight temperature points for computing material properties of each material, and pressure acting on up to three hundred elements. The maximum semi-band width is fifty.

The analysis proceeds from

$$Ax = F, \qquad (1)$$

where A is the stiffness matrix, x is the displacement matrix, and F is the force matrix.

Having determined the displacements from Equation (1), the strains are assumed to follow from

$$B\varepsilon = x, \tag{2}$$

where B is the matrix linking the strains and the displacements, and ϵ is the strain matrix.

Finally, taking the strains from Equation (2), the stresses are found from

$$\sigma = C\varepsilon, \tag{3}$$

where σ is the stress matrix and C is the material stiffness matrix. For isotropic materials, Equation (3) is Hooke's Law.

1.3 FUTURE WORK

As stated in Section 1.1, PLSTR has undergone a substantial modification since being received by AFFDL/FBC. Future modifications now being considered are using SPLINE interpolation functions to incorporate non-linear material properties, a plane strain option, the ability to run multiple load cases, and a failure criterion for developing margins of safety.

PART II

INPUT INSTRUCTIONS

The input for PLSTR consists of eight logical cards. It must be noted that a logical card may consist of more than one physical card. For the remainder of this section, a logical card will be referred to simply as a card.

The eight input cards needed to run PLSTR are formatted as follows:

CARD 1: Title

CARD 1:	IILIE		
<u>Columns</u>	Format	<u>Variable</u>	<u>Explanation</u>
1 - 80	8A10	HED	Any alphanumeric information necessary to identify the problem
CARD 2:	Basic Inform	mation	
Columns	Format	<u>Variable</u>	<u>Explation</u>
1 - 5	15	NUMNP	Number of grid points
6 - 10	15	NUMEL	Number of elements
11 - 15	15	NUMMAT	Number of materials
16 - 20	15	NUMPC	Number of pressure cards (See Card 7)
21 - 30	F10.2	ACELR	Acceleration in x-direction
31 - 40	F10.2	ACELZ	Acceleration in y-direction
41 - 50	F10.2	Q	Reference (stress-free) temperature
CARD 3:	Material I	dentification	
Columns	Format	<u>Variable</u>	Explanation
1 - 5	15	MTYPE	Material Identification Number

NTC (MTYPE)

Number of temperature cards

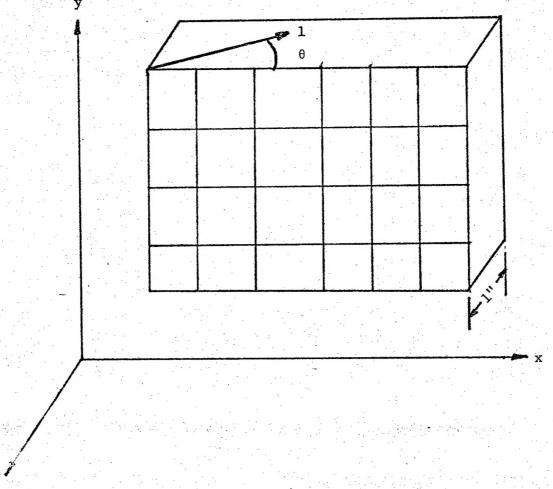
for material MTYPE (see Card 4)

<u>Columns</u>	Format	<u>Variable</u>	<u>Explanation</u>
11 - 20	F10.0	RO(MTYPE)	Mass density for material MTYPE
21 - 25	15	NORTHO (MTYPE)	Material type for material MTYPE 0, ISOTROPIC MATERIAL 1, orthotropic material

CARD 3A: Material Orientation (Orthotropic Materials Only)

Columns	Format	Variable	<u>Explanation</u>
1 - 10	F10.0	Angle, θ	Orientation angle of material longitudinal strength direction
			(fiber direction for dilamentary composites) in x-z plane

Figure 2-1. Grid Geometry



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			T	/T b	Materials Only)
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<u>Columns</u>	Format	<u>Variable</u>	<u>Explanation</u>
1 - 10	F10.3	E(I,1,MTYPE)	Temperature I
11 - 20	F10.3	E(1,2,MTYPE)	Young's Modulus at temperature I
21 - 30	F10.3	E(I,3,MTYPE)	Poisson's Ratio at temperature I
31 - 40	F10.3	E(I,4,MTYPE)	Coefficient of thermal expansion at temperature I

NOTE: Repeat Card 4A for each temperature desired for material MTYPE, i.e., repeat NUMTC(MTYPE) times.

CARD 4B: Material Properties (Orthotropic Materials Only)

<u>Columns</u>	<u>Format</u>	<u>Variable</u>	Explanation
1-10	F10.0	TMAT(MTYPE, I)	Temperature I
11 - 20	F10.0	E11(MTYPE,I)	Longitudinal Young's modulus at temperature I
21 - 30	F10.0	E22(MTYPE,I)	Transverse Young's modulus at temperature I
31 - 40	F10.0	G12(MTYPE,I)	Shear modulus in the 1,2 plane at temperature I
41 - 50	F10.0	AMU12(MTYPE,I)	Poisson's Ratio, v ₁₂ , at
			temperature I
51 - 60	F10.0	Al(MTYPE,I)	Longitudinal coefficient of thermal expansion at temperature I
61 - 70	F10.0	A2(MTYPE,I)	Transverse coefficient of thermal expansion at temperature I
71 - 80	F10.0	A12(MTYPE,I)	Shearing coefficient of thermal expansion, α_{12} , at temperature I

NOTE FOR Al2(MTYPE,I) - At this time α_{12} has not been incorporated into the analysis; it has been included in the input with possible future inclusion in mind. For orthotropic materials $\alpha_{12} = 0$.

NOTE: Repeat Card 4B for each temperature desired for material MTYPE,

i.e., repeat NUMTC(MTYPE) times.

Cards 3 and 4 are repeated NUMMAT times.

CARD	5:	Grid Point Data	
	-		

Columns	Format	<u>Variable</u>	<u>Explanation</u>
1 - 5	15	N	Grid point number
6 - 10	F5.1	CODE (N)	Boundary condition flag for grid point N: 0, UR(N) and UZ(N) are x and y loads 1, UR(N) is x-displacement and UZ(N) is y-load 2, UR(N) is x-load and UZ(N) is y-displacement 3, UR(N) and UZ(N) are x and y displacements
11 - 20	F10.4	R(N)	X-coordinate of grid point N
21 - 30	F10.4	Z(N)	Y-coordinate of grid point N
31 - 40	F10.4	UR(N)	X-load or displacement of grid point N(See CODE(N) above)
41 - 50	F10.4	UZ(N)	Y-load or displacement of grid point N (See CODE(N) above)
51 - 60	F10.4	T(N)	Temperature of grid point N

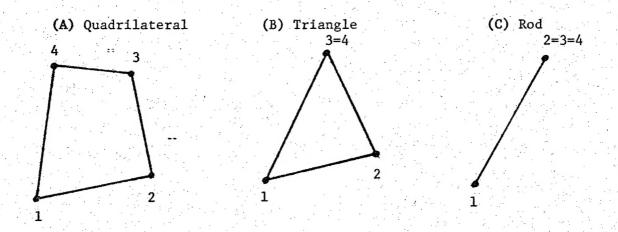
Card 5 is repeated to input the entire grid system. The repetition is performed either for every grid point or for those grid points required by the mesh generator within PLSTR (See Appendix A).

CARD 6: Element Data

Columns	Format	<u>Variable</u>	Explanation
1 - 5	15	M	Element number
6 - 10	15	IX(M,1)	First grid point for element M
11 - 15	15	IX(M, 2)	Second grid point for element M
16 - 20	15	IX(M,3)	Third grid point for element M
21 - 25	15	IX(M,4)	Fourth grid point for element M
26 - 30	15	IX(M,5)	Material identification for element M

As for Card 5, Card 6 is repeated either for every element or for those elements required by PLSTR's mesh generator (See Appendix A). The sequencing of grid points for an element is counter clockwise as shown in Figure 2-2.

Figure 2-2 Element Grid Point Sequencing



NOTE: Four grid points must be input for each element type.

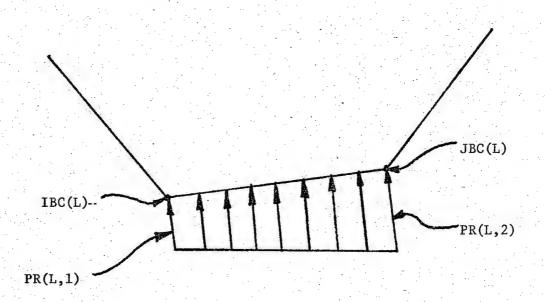
CARD 7: Pressure Data (If NUMPC is greater than zero)

Columns	<u>Format</u>	<u>Variable</u>	Explanation
1 - 5	15	IBC(L)	First pressure grid point
6 - 10	15	JBC(L)	Second pressure grid point
11 - 20	F10.3	PR(L,1)	Pressure acting at IBC
21 - 30	F10.3	PR(L,2)	Pressure acting at JBC

Card 7 is repeated NUMPC times (See Card 2). The grid points are sequenced in a counter clockwise manner as you proceed around the perimeter of the

grid (See Figure 2-3). A linear distribution is assumed along the element face.

Figure 2-3 Pressure Card Nomenclature



CARD 8:	Output	Selection

Format

Columns

1 - 5 I5 NPRT	Stress-Strain output flag
	0, print for each element
	El. No., x,y, x-stress, y-stress,
	xy-stress, max-stress, min-stress,
	and angle
	1, print for each element El. No.,

Explanation

x,y, x-stress, y-stress, xy-stress, x-strain, y-strain, and xy-strain

Variable

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APPENDIX A

PLSTR MESH GENERATOR

The mesh generator in PLSTR is loacted between labeled statement 60 (Line 34) and labeled statement 190 (Line 68) of the main program (See Appendix B). This generation scheme is useful in reducing the required number of physical input cards when many orderly, similarly sized elements occur in the grid.

The impact on grid cards needed is that, if the N + 1 consecutive grid points, M to M + N, are evenly spaced the variable, CODE, for each of these points is zero, and no loads are applied only the grid points M and M + N need be entered. The generator will calculate

$$DX = \frac{X_{M+N-X_M}}{P_{M+N-X_M}}$$

and

$$DY = \frac{Y_{M+N-Y_M}}{N}$$

Then the mesh generator will assign

$$X_{M+1} = X_M + DX, Y_{M+1} = Y_M + DY$$

$$X_{N+2} = X_{M+1} + DX, Y_{M+2} = Y_{M+1} + DY$$

Temperature will be handled in the same manner, and CODE for all generated points will be set to zero.

The impact of the mesh generator on the number of element cards needed is similar to the impact on grid cards. If the N + 1 consecutive elements, M to M + N, have grid points progressing by ones, and the material is the same for all N + 1 elements, only the elements M and M + N need be entered. The mesh generator will assign

$$IX(J,K) = IX(J-1,K) + 1$$
 $J = M+1,M+N; K=1,4$

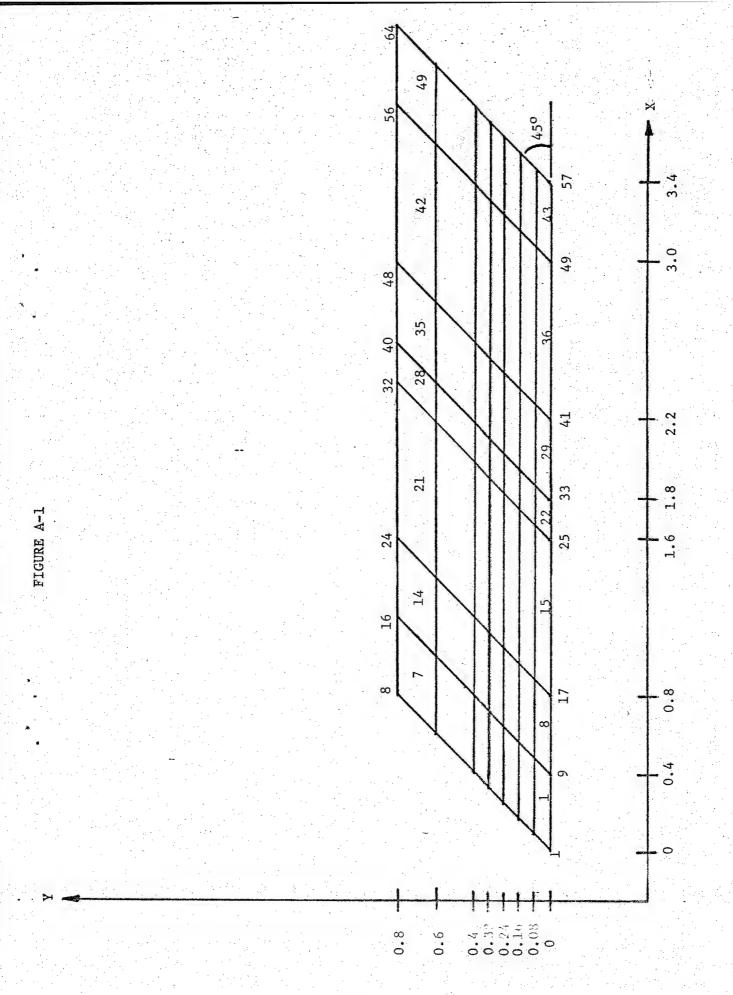
and

$$IX(J,5) = IX(M,5)$$
 $J = M+1,M+N-1$

The following examples will illustrate the use and effect of the mesh generator.

EXAMPLE 1. Take a grid consisting of 64 grid points and 49 elements (See Figure A-1). In this problem, assume material 1 exists from Y = 0.0 to 0.32, and material 2 exists from Y = 0.32 to 0.8. Also assume that no points are constrained, i.e., CODE is zero everywhere. Without a mesh generator, 64 grid point cards and 49 element cards would be needed.

The grid points which <u>must</u> be input for this problem are 1,6,8,9,14, 16,17,22,24,25,30,32,3338,40,41,46,48,49,54,56,57,62,64. Thus, only 24 grid points need be input instead of 64. The elements which <u>must</u> be input are 1,4,5,7,8,11,12,14,15,18,19,21,22,25,26,28,29,32,33,35,36,39,40,42,43,46,47,49. Therefore, only 28 elements need be input instead of 49. In this problem, the mesh generator causes 61 fewer cards to be required.



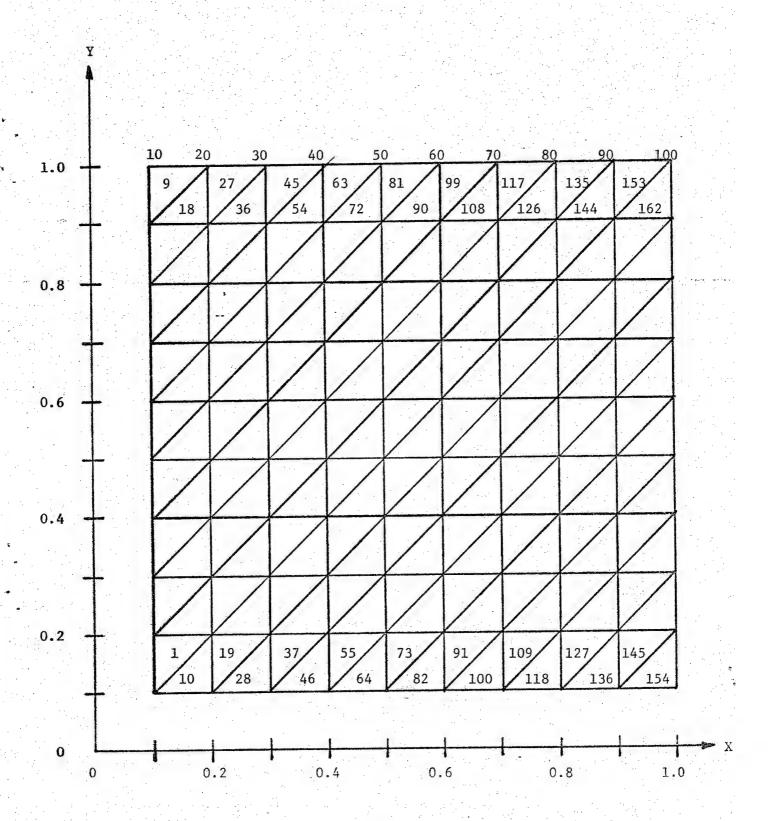
EXAMPLE 2. Take the same grid as in example 1. Assume, this time, that loads are applied at grid points 1 to 8, a zero x-displacement is imposed at grid points 57 to 64, and only one material is used.

The grid points which must be input for this problem are 1-8,9,14,16,17, 22,24,25,30,32,33,38,40,41,46,48,49,54,56,57-64. The elements which must be input are 1,7,8,14,15,21,22,28,29,35,36,42,43, and 49. Since only 34 grid points and 14 elements are input, 65 fewer data cards are required because of the mesh generator.

EXAMPLE 3. Take a grid consisting of 100 grid points and 162 elements (See Figure A-2). Assume one material, no loads, and no constraints. Without the mesh generator, 262 data cards would be required.

The grid points which must be input are 1, 10,11,20,21,30,31,40,41,50,51,60,61,70,71,80,81,90,91, and 100. The elements which must be input are 1,9,10,18,19,27,28,36,37,45,46,54,55,63,64,72,73,81,82,90,91,99,100,108,109,117,118,126,127,135,136,144,145,153,154, and 162. Thus, only 56 cards are required, instead of 262.

Figure A-2



APPENDIX B

PROGRAM LISTING

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SYMBOLIC REFERENCE MAP

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APPENDIX C

SAMPLE PROBLEM INPUT AND OUTPUT

Take a grid consisting of 64 grid points and 49 elements (See Figure A-1). Assume a distributed load through grid points 1-8 such that the eight respective point loads are 500, 1000, 1000, 1000, 1000, 1000, 1000, and 500 pounds. Assume also that grid points 57-64 are constrained in the x-direction. A constant pressure of 100 psi is applied to the lower surface. The temperature throughout the grid is 70°F, while the stress-free temperature of the structure is 0°F. The structure consists of two materials as follows:

Material 1 (isotropic) exists from y = 0.0 to y = 0.32 and has as properties

$$0^{\circ}$$
 70°
E 10^{6} psi $9 \times 10^{5} \text{ psi}$
 0.3 0.3
 0.3 0.3

Material 2 (orthotropic) exists from y = 0.32 to y = 0.8 at an angle of 0° in the xz-plane and has as properties

	0°		70°
E ₁₁	10 ⁶		9 x 10 ⁵
E ₂₂	10 ⁵		9 x 10 ⁴
G ₁₂	10 ⁵		9.5×10^4
ν ₁₂	0.25		0.25
$^{lpha}_{11}$	5×10^{-6}		6×10^{-6}
α ₂₂	5 x 10 ⁻⁵		6×10^{-5}
α ₁₂	0.0		0.0
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The input and output for this problem is as follows:

SAMPLE INPUT

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SAMPLE OUTPUT

SAMPLE PROBLEM FOR PLSTR USER'S MANUALT EXAMPLE FROM APPENDIX C.

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NUMBER OF PRESSURE CARDS---

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Y-ACCELERATION-------

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IT CAN PLEASE REVIEW ALL YOUR PERMANENT FILES AND PURGE THOSE THAT ARE NOT ABSOLUTELY NECESSARY. PERM. FILES FROM 1864, 28 JAN 73 LOADED AT 1759, 29 JAN 73. CONDUCTED DUKING THE PERIOD (7 FEB THRU 9 FEB 73). PRODUCTION ENVIRONMENT WILL BE TO REGISTER CONTACT TOM KELLER, ASD/DPCD, 56351754442. THE ABOVE PRODUCTS ARE OFFERED FOR TESTING AND MAY MALFUNCTION IN SOME CASES; THEREFORE PLEASE REPORT ANY PROBLEMS AS SOON AS POSSIBLE TO EXT. 56248 AND SAVE SUPPORTING DOCUMENTATION. OFFERED ON (07u0-0800). A 15 HOUR INTERMEDIATE FIN COURSE WILL BE OFFERED ON MAR 12,14,16,19,21,23 FROM USIO TO 113J IN ROOM 101. A COMPLETE AUDIT IS PUT UN PERM FILE EVERY MORNING. BE ATTACHED BY THE P.F. NAME (AUDIT, CY=4). A 12 & 1/2 HOUR SCOPE COURSE WILL BE OFFERED ON FEB 26,29, MAR 2,7,9 FROM UBUG TO 1130 IN ROOM 101. THE FOLLUWING PRODUCTS WILL BE IN TEST MODE! SYSTEM 2794 WAS INTRODUCED ON UZ JAN 73. TESTING ... MONDAY THEU FRIDAY LIVE TEST IN THE SOFTWARE PRODUCT TEST: SIMSCRIPT 3.0 USEFUL INFORMATION ... SOF TAARE ANNOUNCE MENTS. .. 5 2 ဝ 6 7 3 9 Ĵ À

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